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1.A method to form a VLSI-photonic heterogeneous system device, said

method comprising:

5 providing an optical substrate comprising at least one passive optical component formed therein;

providing an electronic substrate comprising at least one active electronic component formed therein;

10 forming a plurality of metal pillars through said optical substrate and protruding out a first surface of said optical substrate;

forming a plurality of metal pads on a first surface of said electronic substrate; and

bonding together said optical substrate and said electronic substrate by a method further comprising:

15 aligning said first surfaces of said optical and electronic substrates such that said protruding metal pillars contact said metal pads; and

20 thermally treating said optical and electronic substrates such that said metal pillars bond to said metal pads.

2.The method according to Claim 1 wherein said optical

substrate is a wafer comprising a plurality of die, wherein  
each said die comprises at least one said passive optical  
component, wherein said electronic substrate is a wafer  
5 comprising a plurality of die, and wherein each said die  
comprises at least one said active electronic component.

3.The method according to Claim 2 wherein said optical  
wafer and said electronic wafer each contain alignment  
marks so that said wafers can be accurately aligned one to  
another.

4.The method according to Claim 1 wherein said electronic  
substrate comprises a photodetector device, wherein said  
optical substrate transmits an optical signal, and wherein  
a vertical waveguide transmits said optical signal through  
5 said electronic substrate to said photodetector device.

5.The method according to Claim 1 wherein said passive  
optical component is a waveguide, a splitter, a  
multiplexer, a demultiplexer, an add/drop filter, a ring  
resonator, ~~or~~ a waveguide optical switch, or a combination  
5 thereof.

6.The method according to Claim 1 wherein said passive optical component is a thin film, a Si-based waveguide, a silica waveguide, a photonic crystal, or combinations thereof.

7.The method according to Claim 1 wherein said active electronic component is a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing circuit,  
5 a radio frequency processing circuit, a baseband processing circuit, or a combination thereof.

8.The method according to Claim 1 wherein said step of thermally treating is performed at a temperature of between about 100 °C and about 500 °C.

9.The method according to Claim 8 wherein said step of bonding together further comprises a pre-plasma surface treatment of said protruding metal pillars and said metal pads prior to said step of thermally treating.

10.The method according to Claim 1 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

11.The method according to Claim 10 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal  
5 path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

12.The method according to Claim 11 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

13.The method according to Claim 10 wherein said embedded mirror is formed by a method comprising:

forming a cladding layer overlying a silicon layer on said optical substrate;

5 patterning said cladding layer to form openings through said cladding layer where said embedded mirror is planned;

depositing a waveguide layer overlying said cladding layer and filling said openings;

10 patterning said waveguide layer to define said waveguide wherein said patterning forms an angled edge

where said waveguide layer is etched through to underlying  
said cladding layer;

depositing a metal layer overlying said waveguide; and  
15        patterning said metal layer to remove said metal layer  
from said waveguide excepting at said angled edge of said  
waveguide wherein said metal layer forms an embedded mirror  
for said waveguide.

14. The method according to Claim 13 wherein said step of  
patterning said cladding layer and said step of patterning  
said metal layer use the same photolithographic mask.

15. The method according to Claim 13 further comprising  
depositing a second cladding layer overlying said  
waveguide.

16. The method according to Claim 15 wherein said second  
cladding layer comprises a thickness of less than about  
5,000 Å such that chemical or biological agents contacting  
said second cladding layer will affect evanescent light  
5        when an optical signal is transmitted in said waveguide.

17. The method according to Claim 15 wherein said waveguide  
has parallel trenches or is based on a photonic crystal

device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or photonic crystal device to thereby affect evanescent light when an optical signal is transmitted in said waveguide.

18.The method according to Claim 1 wherein said optical substrate comprises a silicon layer and a dielectric layer, wherein said dielectric layer contains said passive optical component, and wherein said dielectric layer is at said first surface, and further comprising removing said silicon layer from said dielectric layer after said step of bonding together said optical substrate and said electronic substrate.

19.The method according to Claim 1 wherein said optical substrate comprises a thick dielectric layer and further comprising:

depositing a metal layer overlying said thick dielectric layer on the surface opposite said electronic substrate after said step of bonding together; and patterning said metal layer to form metal lines.

20.The method according to Claim 19 wherein said metal lines form a low loss transmission line, an inductor, or an antenna.

21.The method according to Claim 19 wherein said thick dielectric layer has a thickness of between about 10  $\mu\text{m}$  and about 50  $\mu\text{m}$ .

22.The method according to Claim 1 wherein said passive optical component comprises a waveguide and further comprising:

5       patterning said optical substrate to form an opening through a part of said waveguide after said step of bonding together; and

          placing a laser diode in said opening such that light from said laser diode will enter said waveguide.

23.The method according to Claim 22 wherein said waveguide further comprises an embedded mirror and wherein said electronic substrate comprises:

          a vertical waveguide; and  
5       a photodetector device such that said laser diode light will be transmitted through said optical substrate

waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

24. The method according to Claim 1 further comprising:

etching said optical substrate after said step of bonding together such that said metal pillars protrude out of said optical substrate at a second surface opposite said electronic substrate;

providing a third substrate with metal pads on a first surface; and

bonding together said optical substrate and said third substrate by a method further comprising:

aligning said second surface of said optical substrate and said first surface of said third substrate such that said protruding metal pillars contact said metal pads; and

thermally treating said optical and third substrates such that said metal pillars bond to said metal pads.

25. The method according to Claim 24 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one

5 passive optical component formed therein.

26.A method to form a waveguide with an embedded mirror in  
the manufacture of an optical substrate device, said method  
comprising:

forming a cladding layer overlying a silicon layer on  
5 an optical substrate;

patterning said cladding layer to form openings  
through said cladding layer where an embedded mirror is  
planned;

depositing a waveguide layer overlying said cladding  
10 layer and filling said openings;

patterning said waveguide layer to define a waveguide  
wherein said patterning forms an angled edge where said  
waveguide layer is etched through to underlying said  
cladding layer;

15 depositing a metal layer overlying said waveguide; and  
patterning said metal layer to remove said metal layer  
from said waveguide excepting at said angled edge of said  
waveguide wherein said metal layer forms an embedded mirror  
for said waveguide.

27.The method according to Claim 26 wherein said step of patterning said cladding layer and said step of patterning said metal layer use the same photolithographic mask.

28.The method according to Claim 26 further comprising depositing a second cladding layer overlying said waveguide.

29.The method according to Claim 26 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light when an optical signal is transmitted in said waveguide.

30. The method according to Claim 29 wherein said waveguide has parallel trenches or is based on a photonic crystal device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or photonic crystal device to thereby affect evanescent light when an optical signal is transmitted in said waveguide.

31.A VLSI- photonic heterogeneous system device, said device comprising:

an optical substrate comprising:

at least one passive optical component formed  
5 therein; and

a plurality of metal pillars through said optical  
substrate and protruding out a first surface of said  
optical substrate; and  
an electronic substrate comprising:

10 at least one active electronic component formed  
therein; and

a plurality of metal pads on a first surface of  
said electronic substrate wherein said first surfaces  
of said optical substrate and said electronic  
15 substrate are held together by the bonding between  
said metal pillars and said metal pads.

32.The device according to Claim 31 wherein said optical  
substrate is a wafer comprising a plurality of die, wherein  
each said die comprises at least one said passive optical  
component, wherein said electronic substrate is a wafer  
5 comprising a plurality of die, and wherein each said die  
comprises at least one said active electronic component.

33.The device according to Claim 32 wherein said optical  
wafer and said electronic wafer each contain alignment

marks so that said wafers can be accurately aligned one to another.

34. The device according to Claim 31 wherein said electronic substrate comprises a photodetector device, wherein said optical substrate transmits an optical signal, and wherein a vertical waveguide transmits said optical  
5 signal through said electronic substrate to said photodetector device.

35. The device according to Claim 31 wherein said passive optical component comprises a waveguide, a splitter, a multiplexer, a demultiplexer, an add/drop filter, a ring resonator, or a waveguide optical switch.

36. The device according to Claim 31 wherein said active electronic component comprises a Si modulator, a trans-impedance amplifier, a clock recovery circuit, a laser driver circuit, a multiplexing circuit, a demultiplexing  
5 circuit, a radio frequency processing circuit, or a baseband processing circuit.

37.The device according to Claim 31 wherein said passive optical component comprises a waveguide and wherein said waveguide further comprises an embedded mirror.

38.The device according to Claim 37 wherein said electronic substrate comprises:

a vertical waveguide; and

a photodetector device such that an optical signal  
5 path is formed through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

39.The device according to Claim 38 wherein said vertical waveguide and said optical substrate waveguide comprise the same material.

40.The device according to Claim 37 wherein said embedded mirror is formed by a method comprising:

forming a cladding layer overlying a silicon layer on said optical substrate;

5 patterning said cladding layer to form openings through said cladding layer where said embedded mirror is planned;

depositing a waveguide layer overlying said cladding layer and filling said openings;

10        patterning said waveguide layer to define said waveguide wherein said patterning forms an angled edge where said waveguide layer is etched through to underlying said cladding layer;

          depositing a metal layer overlying said waveguide;

15        patterning said metal layer to remove said metal layer from said waveguide excepting at said angled edge of said waveguide wherein said metal layer forms an embedded mirror for said waveguide; and

          depositing a second cladding layer overlying said

20        waveguide.

41. The device according to Claim 40 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light

5        when an optical signal is transmitted in said waveguide.

42. The method according to Claim 40 wherein said waveguide has parallel trenches or is based on photonic crystal device and wherein chemical or biological agents will be trapped in said trenches or in holes in said waveguide or

5 photonic crystal device to thereby affect evanescent light  
when an optical signal is transmitted in said waveguide.

43.The device according to Claim 31 wherein said optical  
substrate further comprises:

a thick dielectric layer; and

patterned metal lines overlying said thick dielectric  
5 layer on the surface opposite said electronic substrate.

44.The device according to Claim 43 wherein said patterned  
metal lines form a low loss transmission line, an inductor,  
or an antenna.

45.The device according to Claim 44 wherein said thick  
dielectric layer has a thickness of between about 10  $\mu\text{m}$  and  
about 50  $\mu\text{m}$ .

46.The device according to Claim 31 wherein said optical  
substrate further comprises:

a waveguide; and

a laser diode in an opening in said optical substrate  
5 and aligned such that that light from said laser diode will  
enter said waveguide.

47.The device according to Claim 46 wherein said waveguide further comprises an embedded mirror and wherein said electronic substrate comprises:

a vertical waveguide; and

5 a photodetector device such that said laser diode light will be transmitted through said optical substrate waveguide, to said embedded mirror, through said electronic substrate vertical waveguide, and to said photodetector.

48.The device according to Claim 46 wherein said waveguide is based on a photonic crystal device.

49.The device according to Claim 31 further comprising a third substrate comprising a plurality of metal pads on a first surface of said third substrate wherein a second surface of said optical substrate, opposite from said electronic substrate, and said first surface of said third substrate are held together by the bonding between said metal pillars and said third substrate metal pads.

50.The method according to Claim 49 wherein said third substrate comprises either an electronic substrate comprising at least one active electronic component formed therein or an optical substrate comprising at least one

5 passive optical component formed therein.

51.A waveguide device with an embedded mirror, said device comprising:

a cladding layer overlying a silicon layer on an optical substrate wherein said cladding layer has openings  
5 through to underlying silicon layer;

a patterned waveguide layer overlying said cladding layer and partially filling said openings wherein said patterned waveguide layer has an angled edge in said openings;

10 a metal layer overlying said waveguide only on said angled edge; and

a second cladding layer overlying said waveguide layer and said metal layer.

52.The device according to Claim 51 wherein said second cladding layer comprises a thickness of less than about 5,000 Å such that chemical or biological agents contacting said second cladding layer will affect evanescent light  
5 when an optical signal is transmitted in said waveguide.

53.The method according to Claim 51 wherein said waveguide comprises a photonic crystal material and wherein chemical

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or biological agents will be trapped in holes in said  
photonic crystal material to thereby affect evanescent  
5 light when an optical signal is transmitted in said  
waveguide.